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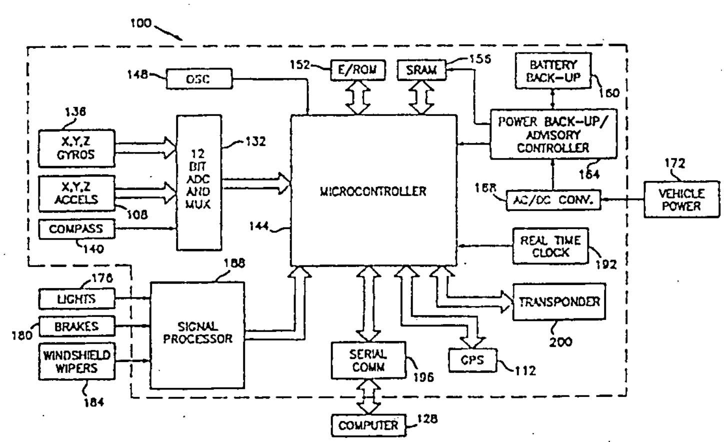


(57) Abstract

A vehicle data recorder, utilized to record vehicle operational data, employs accelerometers to sense vehicle acceleration. To compensate for the inherent error in such accelerometers due to their undesired response to gravity, a gyroscope is employed. The gyroscope measures the identical false acceleration component, due to vehicle inclination, as that of the accelerometers. The gyroscope outputs are then subtracted from the accelerometer outputs, resulting in a true reading of vehicle acceleration, from which vehicle velocity is calculated. The vehicle data recorder also includes a communications port for connection to a computer utilized to reconstruct an abnormal vehicle operating condition. Also included is a signal transmitter for sending signals to appropriate rescue authorities and indicative of vehicle conditions such as the vehicle location, the severity of the accident and the time of the accident. A global positioning system is also utilized to allow the vehicle to determine its location on the earth's surface.

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VEHICLE CRASH DATA RECORDER, LOCATOR AND COMMUNICATOR

## BACKGROUND OF THE INVENTION

This invention relates to data recorders for vehicles such as automobiles, and more particularly to such a data recorder having improved means for sensing vehicle acceleration prior to and during an abnormal vehicle operating condition, such as a vehicle crash.

When any type of air, water or land vehicle encounters a problematic or abnormal operating condition, such as an accident in which the vehicle strikes an object, it is desirable to determine the reasons for such a condition. This is especially important when human injury or loss of life occurs.

Historically, the reasons or causes for a vehicle accident have been determined by making an estimate of various vehicle operating parameters, such as velocity and direction. These estimates are made from readily-observable evidence, such as the length and direction of tire skid marks left on the surface of the roadway, and the amount and type of damage to the vehicle. The resulting observed values are then cross-referenced to empirical look-up tables containing relevant values for corresponding vehicle velocity and direction. These tables have been developed over time based upon the laws of physics, vehicle materials and data available from thousands of vehicle accidents.

However, this approach to determining the velocity and direction of a vehicle both prior to and at the time of an accident does not yield truly accurate data. Data accuracy is inherently limited by the fact that a certain length of tire skid marks could be caused by different vehicle speeds and various other conditions. Other factors could contribute to the skid marks, including the amount of tire tread, type of road surface (*e.g.*, asphalt, concrete, *etc.*), and the condition of the road surface (*e.g.*, dry, wet from rain, ice covered, snow covered, *etc.*). Based on the shortcomings of the empirical table look-up method, it is desirable to utilize a more accurate and scientific means and method for determining vehicle operating parameters, such as velocity, at the time of a vehicle accident or other abnormal vehicle operating condition.

It is well-known in the art of aircraft to utilize a data recorder (a.k.a., "a black box") for continuously or selectively monitoring and storing data associated with various aircraft flight parameters. Upon the crash of an aircraft, the black box is

recovered. The data in the black box is then typically downloaded to a computer. The computer executes software that recreates various flight conditions which occurred in conjunction with an abnormal aircraft situation, such as a crash or an unexpected evasive maneuver. The use of such flight data recorders on aircraft is usually mandated by law, due in part to the fact that an aircraft crash most always results in loss of large numbers of human life. Thus, the need to have a recorder on-board the aircraft generally outweighs any cost considerations.

However, in the case of land and water vehicles (*e.g.*, cars, boats), this need/cost analysis historically has resulted in the exclusion of data recorders on such vehicles. Various factors have contributed to this decision, including that a significantly larger number of land and water vehicles exist as compared to aircraft, that the cost of such land and water vehicles is much less than aircraft (nevertheless the cost of such land and water vehicles is certainly influential when consumers are deciding whether to purchase such a vehicle, such that the cost of every component of a car or boat is strictly considered by its manufacturer), and that the occurrence of an accident or other abnormal operating condition associated with such land and water vehicles often does not result in serious human injury or loss of life. Indeed, as compared to various types of aircraft, no known similar laws exist mandating the usage of such data recorders on land or water vehicles.

Nevertheless, a number of prior art patents exist which describe a data recorder for use not only on aircraft but also on cars, boats and other non-aircraft vehicles. Examples of these prior art data recorders are provided in U.S. Pat. Nos. 3781824, 4638289, 5446659 and 4992943. In general, these and other prior art data recorders are somewhat similar to existing aircraft flight data recorders in that they sense or monitor various vehicle operating parameters and then utilize various schemes for storing data for later readout and vehicle operation reconstruction. The differences between aircraft data recorders and land or water vehicle data recorders reside primarily in the types of parameters sensed and stored. This is due to the inherent structural differences between these types of vehicles and in the resulting physical operating parameters involved. Yet, many similarities exist in data recorders for all three types of vehicles.

Despite the teachings of these patents, the prior art data recorders remain largely unavailable for vehicles such as consumer-purchased cars, trucks and boats. Reasons for such unavailability were discussed, in part, above. However, the inventors theorize that perhaps the cost of implementing such a data recorder on an automobile historically has been the primary reason for its exclusion. Nevertheless, rapid advances in integrated circuit semiconductor technology has reduced the size and cost, while improving the functionality and availability, of various types of sensors and signal processors. However, another reason for their unavailability on automobiles may exist, as discussed below.

With respect to any type of vehicle, perhaps the most important and desired operating parameter used in reconstructing the operation of the vehicle just prior to and during an accident is vehicle speed. As is well-known (for example, as taught by the aforementioned patents), velocity is usually (if not always) determined by these vehicle data recorders through the use of an accelerometer. The accelerometer senses the amount of vehicle acceleration (usually in a predetermined direction of travel), and this value is integrated mathematically to obtain vehicle velocity. None of the above patents, or any other known patents, teach the use of a vehicle acceleration measuring device, either in conjunction with or instead of, the well-known accelerometer.

However, the use of solely an accelerometer to measure vehicle acceleration often times leads to errors and inaccuracies in the sensed acceleration value. The error introduced into the accelerometer output is an undesirable and false amount of vehicle acceleration due to the incline or "tilt" of the accelerometer when the vehicle is not level.

Most accelerometers utilize both a mass and a flexing beam to sense acceleration. Any tilting of the sensor from a zero horizontal angular position will cause the accelerometer to incorrectly interpret such tilting as an acceleration value. This situation can occur most often simply when the vehicle is driving up or down an inclined surface. It can also occur during a collision when the car bounces, raises or acts as a projectile. The false reading adds to the true measure of any vehicle acceleration sensed by the accelerometer.

The proportional amount of the false acceleration component with respect to the overall sensed acceleration output is at its relatively largest value during

small amounts of acceleration; that is, during normal driving conditions. It can also be important during the duration of a collision. Therefore, for use in a vehicle data recorder that records acceleration data just prior to an accident or crash, the use of an accelerometer can produce a significant false acceleration component.

Accordingly, it is a primary object of the present invention to provide a vehicle data recorder that overcomes the shortcomings of prior art accelerometers.

It is a general object of the present invention to provide a vehicle data recorder that utilizes an accelerometer, but compensates for any erroneous effects that gravity has on the value of the accelerometer output.

It is another object of the present invention to "decouple" the effects of gravity on an accelerometer to obtain an accurate reading of vehicle acceleration.

It is yet another object of the present invention to provide a vehicle data recorder that can distinguish between desired data indicative of true vehicle acceleration and spurious data indicative of the effects of gravity on the accelerometer.

Still another object of the present invention is to provide a vehicle data recorder that accurately measures and records data relating to various vehicle parameters, to thereby assist in the scientific recreation of the motion of the vehicle at predetermined periods of vehicle operation.

Yet another object of the present invention is to provide a vehicle data recorder that can also determine the position of the vehicle anywhere on the earth's surface.

Another object of the present invention is to provide a vehicle data recorder that also includes a signal transmitter for transmitting signals indicative of vehicle operating parameters, such as the location of the vehicle at the time of an accident, the severity of the accident and the time of day that the accident occurred.

The above and other objects and advantages of this invention will become readily apparent when the following description is read in conjunction with the accompanying drawings.

## SUMMARY OF THE INVENTION

To overcome the deficiencies of the prior art and to achieve the objects listed above, the Applicants have invented a vehicle data recorder that utilizes an

accelerometer, but also employs a gyroscope to compensate for any errors caused by gravity in the output signal of the accelerometer, thereby providing for a true reading of vehicle acceleration.

In a preferred embodiment of a primary aspect of the present invention, the data recorder is operable to record data associated with various operating parameters of an automobile. The data can be continuously and selectively stored and later retrieved to reconstruct the operation of the vehicle at certain instances in time; for example, just prior to and during a vehicle accident. The recorder of the present invention is of compact design and is typically mounted to the automobile body. The recorder is microprocessor-based, and senses and conditions various electronic signals, including those indicative of vehicle direction and the status of the various vehicle lights, as well as the vehicle brakes and windshield wipers.

The recorder also includes three accelerometers that sense vehicle acceleration in three different directions (*i.e.*, along the X, Y and Z axes or directions of movement), and a three-axis gyroscope. The gyroscope measures the identical amounts of false acceleration values in each axis (*i.e.*, pitch, roll and yaw) that are undesirably measured by the accelerometers due to the tilt of the accelerometers. The microprocessor utilizes the gyroscope output values to cancel the false acceleration values from the accelerometer outputs, thereby producing a true reading of vehicle acceleration from which vehicle velocity can be calculated. The vehicle recorder of the present invention contains memory for storing a predetermined amount of data relating to these various operating parameters.

According to a second aspect of the present invention, the vehicle data recorder also includes a signal transmitter for transmitting signals indicative of certain vehicle conditions to appropriate personnel. For example, once the microprocessor has determined, from the sensed data, that an accident has occurred, the data recorder of the present invention can transmit radio frequency signals to local police and rescue authorities indicative of the location and time of the accident, and the severity of the accident.

According to a third aspect of the present invention, the vehicle data recorder also includes means for determining the location of the vehicle on the earth's

surface. The location determining means may be either satellite-based and/or ground-based, depending upon the type of vehicle and whether it is land or water-based.

According to a fourth aspect of the present invention, an external computer connects to the vehicle data recorder through a communications link. The data stored in the recorder that is indicative of vehicle operating parameters just prior to and during a vehicle crash is downloaded to the computer. The computer executes software that utilizes the downloaded data to accurately and scientifically reconstruct the vehicle accident to assist in determining the reasons or causes of the accident

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustration of the vehicle data recorder of the present invention, as implemented on a vehicle, and utilized with a satellite or land-based global positioning system ("GPS"), and which notifies an entity of the vehicle status;

FIG. 2 is a detailed block diagram illustration of the vehicle data recorder of FIG.1; and

FIG. 3 is a flowchart illustration of software executed by the vehicle data recorder of FIG. 2.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings in detail, there illustrated are exemplary, preferred embodiments of a vehicle data recorder of the present invention having improved means and methodology for accurately sensing the acceleration of a vehicle. The vehicle data recorder, or "ACC" (*i.e.*, "Automobile Crash Coder"), is generally indicated therein by the reference numeral 100. In a preferred exemplary embodiment, the vehicle 104 comprises an automobile. However, it should be understood that the vehicle data recorder 100 of the present invention can be utilized on any type of land, water or air-based vehicle or craft. The primary limitation or consideration is that the vehicle data recorder 100 of the present invention be utilized with accelerometers 108. One or more of these accelerometers 108 are typically used to sense acceleration of the vehicle 104 in a corresponding one or more directions of vehicle travel. The vehicle

data recorder 100 typically contains electronic signal processing means for integrating the output values from the accelerometers 108 to obtain vehicle velocity.

Referring to FIG. 1, there illustrated is the vehicle 104 containing the ACC 100 of the present invention as embodied therein. The vehicle data recorder 100 is described in greater detail hereinafter with respect to FIGS. 2 and 3. As mentioned hereinbefore, the primary functional aspect of the vehicle recorder 100 of the present invention is to compensate for the inherent error when utilizing accelerometers 108 to sense vehicle speed. However, a second primary aspect of the present invention is the provision of means for determining the location of the vehicle 104 anywhere on the earth's surface. To perform this function, the ACC 100 contains a GPS signal receiver/transmitter and corresponding signal processing means 112 (FIG. 2) that receives navigation signals from either earth-orbiting satellites 116 or land-based navigation GPS 120.

In accordance with well-known GPS technology, the GPS signal receiver/transmitter 112, located within the vehicle data recorder 100 of the present invention, may be utilized to receive corresponding directional signals from one or more satellites 116 positioned above the earth's surface. In the alternative, the vehicle data recorder 100 of the present invention may communicate with one or more land-based signal transmitters 120. Both types of GPS systems may typically allow for determination of vehicle location by triangulation. A detailed discussion of such well-known satellite or land-based global positioning systems is given in U.S. Pat. No. 5311197, which is incorporated herein by reference. Described and illustrated in detail in that patent are numerous and various satellite positioning systems, such as the Global Positioning System or the Global Orbiting Navigation System. That patent also describes and illustrates various ground-based radio navigation systems, such as LORAN, SHORAN, DECCA or TACAN.

Other examples of well-known vehicle location systems are described and illustrated in U.S. Pat. Nos. 5119102 and 4740792, both of which patents are incorporated herein by reference. A detailed description of an exemplary GPS is described hereinafter with respect to FIG. 2.

FIG. 1 also illustrates a notified entity 124 that is in communication (typically, radio communication) with the vehicle data recorder 100 of the present

invention. The notified entity 124 may comprise a rescue authority, such as local or state police, fire and/or ambulance. In the alternative, the entity 124 may be a centralized reporting station that receives a signal indication from the recorder 100 of such conditions as the severity of the accident and the time and location of the accident, and reports this information to the appropriate authorities, depending upon the nature of the vehicle abnormal condition.

FIG. 1 also illustrates an external computer 128, or other data processing means, that is in either hardwired or radio communication contact with the vehicle data recorder 100 of the present invention. The computer 128 extracts the information stored in memory in the vehicle data recorder 100 and reconstructs the vehicle abnormal condition from this stored data. In a preferred exemplary embodiment of the present invention, a laptop or desktop computer 128 is utilized, which executes software that extracts the data from the vehicle data recorder 100 through a communications link, and then reconstructs the vehicle abnormal condition.

Referring now to FIG. 2, there illustrated is a detailed block diagram of the vehicle data recorder 100 of the present invention. The ACC or vehicle data recorder 100 preferably comprises those components contained within the dashed lines of FIG. 2. The vehicle data recorder 100 comprises various electronic components, all of which are typically mounted in a hermetically-sealed container that is rigidly affixed to the automobile body. The container of the vehicle data recorder 100 is preferably such that it is able to withstand the normal environment that an automobile is exposed to.

The vehicle data recorder 100 contains three separate accelerometers 108, commercially-available, for example, in the Model DMU-6 Six Axis Dynamic Measurement Unit from Crossbow of San Jose, CA. Each accelerometer 108 is dedicated to sensing acceleration in a specific one of three vehicle directions of travel: X, Y and Z. Typically, the X accelerometer output is indicative of forward vehicle motion, the Y accelerometer output is indicative of lateral or sideways vehicle motion, and the Z accelerometer output is indicative of vertical vehicle motion. In a preferred embodiment, the X-direction accelerometer has a maximum sensitivity of 180 Gs of force, while both the Y and Z accelerometers have relatively much less sensitivity,

typically on the order of 5 Gs. As used herein, the term "G" refers to a unit of force equal to the gravity exerted on a body at rest.

These exemplary values of the maximum sensitivity of the three accelerometers 108 were chosen since it is widely agreed that normal automobile vehicle operation does not result in an acceleration value over 1.5 Gs. For example, published data and automobile manufacturer's technical specifications show that the magnitude of acceleration/deceleration for most passenger cars, busses and trucks normally does not exceed 1.1Gs. On the other hand, a typical car crash may involve a maximum deceleration force of approximately 65 Gs. Therefore, the X-direction accelerometer, because it is less sensitive than the Y and Z-direction accelerometers, will record vehicle acceleration data during the entire duration of the crash. In contrast, the Y and Z-direction accelerometers will typically saturate at some point during an accident, and cease to provide useful data during that accident. However, this sensed available data from both the Y and Z-direction accelerometers will typically provide useful information not only just prior to the vehicle crash but also slightly after the beginning of the crash. However, it should be understood that the chosen maximum values for the three accelerometers 108 are purely exemplary. Other accelerometer values may be utilized, as desired, in light of the teachings of the present invention.

The continuously-sensed acceleration values output from the three accelerometers 108 are provided on signal lines to a twelve-bit analog-to-digital converter ("ADC") and multiplexer ("MUX") 132. The ADC and MUX 132 may comprise a single integrated circuit, commercially-available. Also provided on signal lines to the ADC are the signal outputs from three corresponding gyroscopes 136. In a similar manner to the accelerometers, the three gyroscopes 136 may comprise the Model DMU-6 from Crossbow. As discussed hereinbefore, the gyroscopes are utilized to overcome the inherent problem with the accelerometers in that the gyroscopes will measure the amount of "tilt", in an identical amount to that measured (undesirably) by the accelerometers. In other words, the gyroscopes are sensitive only to tilting of the vehicle data recorder 100, for example, due to vehicle travel on an inclined roadway, and are insensitive to accelerations. As discussed hereinafter in detail, the identical gyroscope outputs are then subtracted from the accelerometer outputs by subsequent signal processing electronics to yield a true indication of vehicle acceleration.

A compass 140 is also provided within the vehicle data recorder 100 of the present invention. The compass 140 provides a signal indicative of absolute vehicle direction on a signal line to the ADC 132. The function of the ADC 132 is to digitize the analog inputs from the gyroscopes 136, accelerometers 108 and the compass 140, and to provide digitized values on signal lines to a microcontroller 144. The microcontroller 144 forms the central signal processing means of the vehicle data recorder 100 of the present invention. The microcontroller 144 may comprise the Zilog or Hitachi Z180, or other similar commercially-availablemicroprocessors. The primary function of the microcontrolleris to interface with all of the elements of the vehicle data recorder 100 of the present invention and direct the corresponding signal processing functions carried out thereby.

An oscillator 148 provides a square-wave signal at an exemplary frequency of 9 megahertz ("MHZ") to the microcontroller 144. The microcontroller may contain certain amounts of various types of on-board memory, or the memory may be physically separate from the micro-controller. FIG. 2 illustrates erasable read only memory (E/ROM) 152, which is non-volatile memory used to store the software instructions executed by the microcontroller 144 in carrying out the functions of the vehicle data recorder 100 of the present invention. FIG. 2 also illustrates volatile static SRAM memory 156, which stores the sensed data from the gyroscopes 136, accelerometers 108, the compass 140 and the various other vehicle devices and systems, described hereinafter. In an exemplary embodiment, 128 K of SRAM memory 156 is provided.

As is well-known, the accuracy of the digital representation of any analog quantity is strongly dependent on the sampling rate of the analog-to-digital converter 132 utilized. In the present preferred exemplary embodiment, to be able to calculate the vehicle velocity with an acceptable accuracy, the microcontroller 144 must acquire data at a minimum of approximately 50 samples per second. After performing the necessary integration of acceleration to determine velocity, the microcontroller writes the calculated velocity data to the SRAM five times per second. Typically, every set of data occupies six bytes of SRAM memory locations. With 128 K of SRAM and a per-channel sampling rate of five, the vehicle data recorder 100 of the present

invention can store up to one hour of vehicle velocity information. However, these capacities are purely exemplary.

A one farad capacitor serves as a battery back-up 160 to the SRAM 156 in the event that the vehicle data recorder 100 loses power. The battery back-up 160 initially connects with a power back-up/advisory controller 164, which may be the commercially-available Model ADM691 integrated circuit.

The advisory controller 164 connects to an AC/DC converter 168, which is connected to the vehicle alternator 172 or power source. The AC/DC converter 168 provides power to all of the electronics within the vehicle data recorder 100 of the present invention. The power back-up/advisory controller 164 monitors the status of the vehicle power and switches the battery back-up 160 to the SRAM 156 in the event that the vehicle power goes below a certain predetermined value.

The power back-up/advisory controller 164 also prevents any data from being written to the SRAM 156 when the electrical power to the electronics within the vehicle data recorder 100 falls below a predetermined threshold. The advisory controller 164 further provides a watch dog timer that guards against system or software faults by resetting the microcontroller 144 if the software does not reset a timer within predetermined repetitive time intervals. In addition, the advisory controller 164 generates a non-maskable interrupt when the vehicle power falls below a predetermined threshold, giving the microcontroller 144 time to execute certain software shut-down routines.

To properly reconstruct a vehicle abnormal condition, such as an automobile accident, it is helpful if further data, regarding various vehicle components, are available. Specifically, with respect to an automobile 104, it is helpful to know the status of the various vehicle lights 176, together with the history of the brakes 180 and windshield wipers 184 in the time period just prior to a vehicle abnormal condition and during such condition. Therefore, the vehicle data recorder 100 of the present invention provides a signal processor 188 that interfaces to the vehicle lights 176, brakes 180, and windshield wipers 184, and conditions these signals prior to feeding them to the microcontroller 144. The signal processor 188 may merely comprise corresponding voltage divider networks, together with capacitor filters.

A real time clock 192, which may comprise the Model DS1302 integrated circuit commercially-available, provides time and date functions, plus 31 bytes of scratch pad RAM. The real time clock 192 provides time and date information on a signal line to the microcontroller 144, which utilizes this information to stamp the time and date of the various data prior to storing them in SRAM memory 156. To reduce the amount of memory utilized to store the sensed and/or calculated data, it is preferable that the microcontroller 144 only write the time of last data collection to a protected part of SRAM 156, typically only two bytes of memory. When the external computer 128 retrieves data from memory 156, the computer reads this time of last data collection and automatically stamps the data with the time of day.

The vehicle data recorder 100 of the present invention also includes serial communication circuitry 196 for interfacing between the microcontroller 144 and the external computer 128. The serial communication circuitry 196, which may implement the well-known, industry-standard RS 232 protocol, facilitates the access by the computer 128 to the data stored by the microcontroller 144 in the corresponding memory 156 within the vehicle data recorder 100. Typically, the vehicle data recorder 100 of the present invention collects data values, immediately prior to and during a vehicle abnormal condition, with respect to various vehicle parameters, including: direction of vehicle travel; acceleration of the vehicle 104 at impact; speed of the vehicle at impact; direction of impact; point of impact; time of impact; and the history of vehicle lights 176, brakes 180 and windshield wipers 184. The vehicle data recorder 100 stores this information in the SRAM memory 156. The external computer 128 then accesses this information by downloading it through the serial communications circuitry 196. The computer 128 then uses the data to reconstruct the accident. In an exemplary embodiment, the serial communication circuitry 196 connects to the external computer 128 which executes software that places the relevant data on a central site on the Internet to assist the appropriate personnel in reconstructing the accident.

The external computer 128 contains embedded software that downloads and retrieves the stored data. In a preferred exemplary embodiment, the software is written in the well-known C programming language. The software directs the computer to retrieve the data through the serial communications circuitry, decode the data, convert the data to appropriate engineering values, and extract the information relating

to the status of the brakes, headlights and windshield wipers therefrom, together with the information about the vehicle speed and direction. It is contemplated that the person utilizing the software in the external computer can navigate easily through the data and examine it using on-screen menus. Retrieved data can be saved in, *e.g.*, ASCII format and, perhaps, exported to other software applications running on the external computer 128, or read back in later on by the vehicle data processor 100 for subsequent processing and/or storage.

Also included within the vehicle data processor 100 of the present invention is well-known, commercially-available GPS circuitry 112. In its broadest sense, the GPS circuitry may comprise a signal receiver and transmitter for communicating with various types of satellite or ground-based radio navigation systems, as discussed hereinbefore. The GPS 112 may also include signal processing circuitry which determines the location of the vehicle 104 containing the vehicle data recorder 100 of the present invention from these transmitted radio signals. In the alternative, the microcontroller 144 may operate on the received GPS signals for determining the vehicle location, perhaps by the well-known method of triangulation. While many different types of global positioning systems are commercially-available, it is contemplated that the GPS may comprise the Model Magellan GPS 2000, GPS 4000, or Trailblazer XL. In the alternative, the GPS may comprise the Model Garmin GPS 38, GPS II, GPS 45, or GPS 45 XL. These modern global positioning systems are rapidly decreasing in cost, thereby making them more popular for various consumer applications, such as automobiles.

The primary function of such a GPS 112 is to determine the position, on the earth's surface, of the subject vehicle 104. Once determined, the microcontroller 144 stores this vehicle location continuously in SRAM memory 156. Thus, vehicle location data is also available to the external computer 128 through the serial communication circuitry 196.

However, of significant importance is that the microcontroller 144 can store the location of the vehicle 104 at the exact time of the occurrence of the vehicle abnormal condition, regardless of whether the vehicle is subsequently moved from that position after the occurrence of the abnormal condition. This ability to "freeze" the

vehicle location at the time of accident is of significance when reconstructing the vehicle accident and apportioning liability for improper vehicle operation.

Finally, the vehicle data recorder 100 of the present invention includes a radio signal transponder 200 that interfaces with the microcontroller 144. The transponder 200 transmits various information to different notified entities 124. In an exemplary embodiment, the transponder comprises a radio frequency signal generator, that transmits the aforementioned stored data to the appropriate rescue authorities, such as police, fire and/or ambulance personnel.

The transponder 200 may transmit signals indicative of various vehicle conditions that are directly determined from the sensed data. For example, the microcontroller may contain software that determines the severity of the accident, depending upon the largest magnitude of acceleration sensed by any of the three accelerometers 108. In the alternative, other criteria may exist for determining the severity of the accident.

The transponder 200 may simply be a radio frequency transmitter. On the other hand, the transponder may comprise other communication means, such as a cellular phone or citizens band radio. It suffices for the broadest scope of the present invention that the transponder merely comprise some means of transmitting signals indicative of both the sensed vehicle operating parameter data and operating conditions derived therefrom.

Referring now to FIG. 3, there illustrated is a flowchart of software executed by the microcontroller 144 primarily in reading in the sensed vehicle operational data and calculating vehicle velocity therefrom. This routine may represent one of several routines executed by the microcontroller in implementing the functions of the vehicle data recorder 100 of the present invention. For example, as mentioned hereinbefore, the microcontroller may execute software routines that determine the location of the vehicle 104 based on the radio navigation signals sensed by the GPS signal receiver 112. Further, the microcontrollermy execute software which determines parameters such as the severity of the accident from the sensed acceleration data.

With regard to the software routine of FIG. 3, after an enter step 204, the microcontrollermay execute a step 208 in which it retrieves information regarding the calibration set points of the various sensors used in the vehicle data recorder 100 of the

present invention. This calibration information may be stored as constants in the E/ROM memory 152.

Next, the microcontroller 144 executes a step 212 in which it initializes various variables stored in the SRAM 156. These variables are utilized in the various calculations that the microcontroller will execute in calculating the various vehicle operational parameters.

The microcontroller 144 then executes a step 216 in which it reads the values of the various sensors utilized with the vehicle data recorder 100 of the present invention. Referring also to FIG. 2, those sensors include the three gyroscopes 136, the three accelerometers 108, the compass 140, the vehicle lights 176 (*e.g.*, headlights, taillights, directional lights, parking lights) , the vehicle brakes 180 and the windshield wipers 184. These values are continuously available to the microcontroller for calculation purposes from both the ADC 132 and the signal processor 188 of FIG. 2.

The microcontroller then executes a step 220 in which it calculates true acceleration by subtracting the "tilt" values, output from each of the three gyroscopes 136, from the corresponding accelerometer output values. As discussed in detail hereinbefore, such subtraction or "decoupling" of the gyroscope data from the accelerometer data results in true acceleration readings output from the three accelerometers 108.

The microcontroller 144 then executes a step 224 in which it calculates vehicle velocity in each of the X, Y and Z directions of vehicle travel. The specific velocity values are calculated by integrating the decoupled acceleration data from the three accelerometers 108.

Next, the microcontroller executes a step 228 in which it increments a counter by a value of one. This counter was initially set to zero in the initialized variables step 212. The purpose of this counter is for the microcontroller to read the sensors and calculate the corresponding acceleration and velocity data ten times before it eventually writes this data to memory.

Next, the microcontroller checks, in a test 232, to see if the counter equals a value of ten. If not, the microcontroller branches back to the step 216 where it reads the sensors and calculates acceleration and velocity. Instead, if the counter does equal ten, the microcontroller then resets the counter to zero, in a step 236, and checks,

in a test 240, whether the velocity equals zero. If so, the microcontroller 144 branches back to the step 216 where it reads the sensors and begins the data collection and calculation process over again. Instead, if the velocity does not equal zero, then the microcontroller executes a step 244 where it reads the various sensors. Next, the microcontroller writes the various values of the sensed data to the SRAM memory 156 in a step 248.

The microcontroller 144 then checks, in a test 252, the integrity of the power to the various electronic components within the vehicle data recorder 100 of the present invention. If the power is above a predetermined threshold, the microcontroller then branches to the step 220 where the microcontroller decouples the gyroscope data from the accelerometer data to calculate true vehicle acceleration. The microcontroller then continues on with the routine, as described hereinbefore. Instead, if there is a problem with the power, the routine exits in a step 256.

In general, when the microcontroller 144 writes various data values to the SRAM memory 156, the microcontroller initially writes the data into consecutive memory locations until those locations have been filled. While writing the data to the memory, the microcontroller may stamp or assign the time-of-day to each data value in the manner previously described. Once the memory has been filled by the microcontroller, any new data then gets written over the oldest data. In this way, the memory will always contain the most recent data pertaining to vehicle operation. Depending upon the amount of SRAM memory 156 provided, together with the number of sensors within the vehicle data recorder 100 of the present invention, and the sampling rate of the ADC 132, typically the vehicle data recorder 100 of the present invention can store anywhere from 1 to 5 hours of data for subsequent retrieval and vehicle accident reconstruction.

Generally, vehicle data is continuously recorded during normal vehicle operation. The vehicle data recorder 100 then determines that an accident has occurred when the X-direction accelerometer 108 senses a deceleration value which exceeds a predetermined threshold. For example, it is generally known that, during a typical vehicle accident, a deceleration value of at least 65 Gs will be achieved. Therefore, the software executed by the microcontroller can recognize this threshold as the onset or beginning of an accident and may then restrict the amount of data that is subsequently

written to memory once this threshold has occurred. For example, the microcontroller may write data to memory for the next sixty seconds once that predetermined vehicle deceleration value has been achieved.

Generally, when a vehicle accident has occurred, the microcontroller will continue to sense and write data to memory with regard to the vehicle lights 176, brakes 180 and windshield wipers 184. This data collection may occur for a predetermined period of time, or until the vehicle speed equals zero, or until the vehicle power goes below a predetermined threshold. Also, the X-direction accelerometer would continue to have its data written to memory during the entire duration of the accident. However, since both the Y and Z-direction accelerometers have relatively less maximum sensitivity, these accelerometers 108 would typically saturate at some point during a typical accident, and cease to provide useful data. Yet the measured data from these accelerometers, both prior to the crash and somewhat during the time of the crash, would nevertheless be still written to memory, to assist in the accident reconstruction process.

Typically, the microcontroller 144 may determine the relative direction of the vehicle 104 prior to and during any accident by vector summation of the two acceleration components in the X and Y directions. In the alternative, the compass 140 provides an absolute value of vehicle direction.

The vehicle data recorder 100 of the present invention has been described herein for use on an automobile. However, it is to be understood that the vehicle data recorder may be utilized on any type of land, water or air-based vehicle or craft. It suffices for the broadest scope of the present invention that the vehicle data recorder utilize accelerometers that are affected by gravity such that they produce false acceleration readings when the vehicle is inclined. The vehicle data recorder also provides gyroscopes 136 that measure identical values of tilt or inclination of the vehicle data recorder 100, as those values are also measured, undesirably, by the accelerometers 108. The vehicle data recorder 100 of the present invention then utilizes the gyroscope data to "decouple" the false acceleration components from the accelerometer outputs due to the effects of gravity.

It should be understood by those skilled in the art that obvious structural modifications can be made to the embodiments described and illustrated herein without

departing from the scope of the invention. Accordingly, reference should be made primarily to the accompanying claims, rather than the foregoing specification, to determine the scope of the invention.

Having thus described the invention, what is claimed is:

CLAIMS

1. A device, comprising:

means for sensing acceleration of a vehicle and for providing a sensed acceleration signal indicative thereof, wherein the sensed acceleration signal contains a first component indicative of any acceleration of the vehicle, and wherein the sensed acceleration signal contains a second component indicative of any angular inclination of the acceleration sensing means with respect to a predetermined reference angular level of inclination; and

means for sensing angular inclination of the acceleration sensing means and for providing a sensed inclination signal indicative thereof.

2. The device of Claim 1, further comprising signal processing means, responsive to both the sensed acceleration signal and the sensed inclination signal, for providing an output acceleration signal indicative of the first component of the sensed acceleration signal, and further comprising memory means for selectively storing signals therein.

3. The device of Claim 1, wherein the acceleration sensing means comprises means for sensing acceleration of the vehicle in more than one predetermined directions of vehicle travel and for providing a corresponding directional sensed acceleration signal for each one of the more than one predetermined directions of vehicle travel.

4. The device of Claim 1, wherein the acceleration sensing means comprises at least one accelerometer.

5. The device of Claim 1, wherein the angular inclination sensing means comprises means for sensing the angular inclination of the acceleration sensing means in more than one predetermined directions of vehicle travel, and for providing a corresponding directional sensed angular inclination signal for each one of the more than one predetermined directions of vehicle travel.

6. The device of Claim 2, wherein the second component of the sensed acceleration signal is equal to the sensed inclination signal, and wherein the signal processing means comprises means for comparing the second component of the sensed acceleration signal to the sensed inclination signal and for subtracting a result

of the comparison from the sensed acceleration signal, whereby the first component of the sensed acceleration signal results from the subtraction.

7. The device of Claim 1, wherein the angular inclination sensing means comprises a gyroscope.

8. The device of Claim 2, wherein the signal processing means comprises means for determining velocity of the vehicle from the output acceleration signal and for providing a corresponding velocity signal indicative thereof, the signal processing means comprising means for selectively storing the velocity signal in the memory means.

9. The device of Claim 8, wherein the signal processing means comprises means for selectively assigning a time parameter to the velocity signal stored in the memory means.

10. The device of Claim 8, wherein the signal processing means comprises means, responsive to a signal indicative of at least one vehicle component, for selectively storing the vehicle component signals in the memory means.

11. The device of Claim 10, wherein the at least one vehicle component is selected from the group consisting of vehicle lights, vehicle brakes and vehicle windshield wipers.

12. The device of Claim 10, further comprising communication means for connecting the signal processing means to a computer located external to the device, the external computer comprising means for selectively downloading the vehicle component signals and the velocity signal from the memory means and for reconstructing a vehicle operating condition therefrom.

13. The device of Claim 2, further comprising global positioning means for receiving at least one navigation signal from a radio navigation system located external to the device, wherein the signal processing means comprises means for determining a location of the vehicle from the at least one navigation signal and for providing a vehicle location signal indicative of the determined location of the vehicle, the signal processing means also comprising means for selectively storing the vehicle location signal in the memory means.

14. The device of Claim 13, further comprising transponder means for selectively transmitting the vehicle location signal outside of the device.

15. The device of Claim 2, wherein the signal processing means further comprises means for determining a vehicle operating condition based upon a magnitude of the output acceleration signal and for providing a vehicle operating condition signal indicative of the determined vehicle operating condition, the signal processing means comprising means for selectively storing the vehicle operating condition signal in the memory means.

16. The device of Claim 15, wherein the vehicle operating condition is a severity of contact of the vehicle with another object.

17. The device of Claim 15, further comprising transponder means for selectively transmitting the vehicle operating condition signal outside of the device.

18. The device of Claim 15, wherein the signal processing means comprises means for selectively assigning a time parameter to the vehicle operating condition signal stored in the memory means.

19. The device of Claim 18, further comprising transponder means for selectively transmitting the vehicle operating condition signal outside of the device.

20. The device of Claim 2, further comprising means for determining a direction of travel of the vehicle and for providing a travel direction signal indicative thereof.

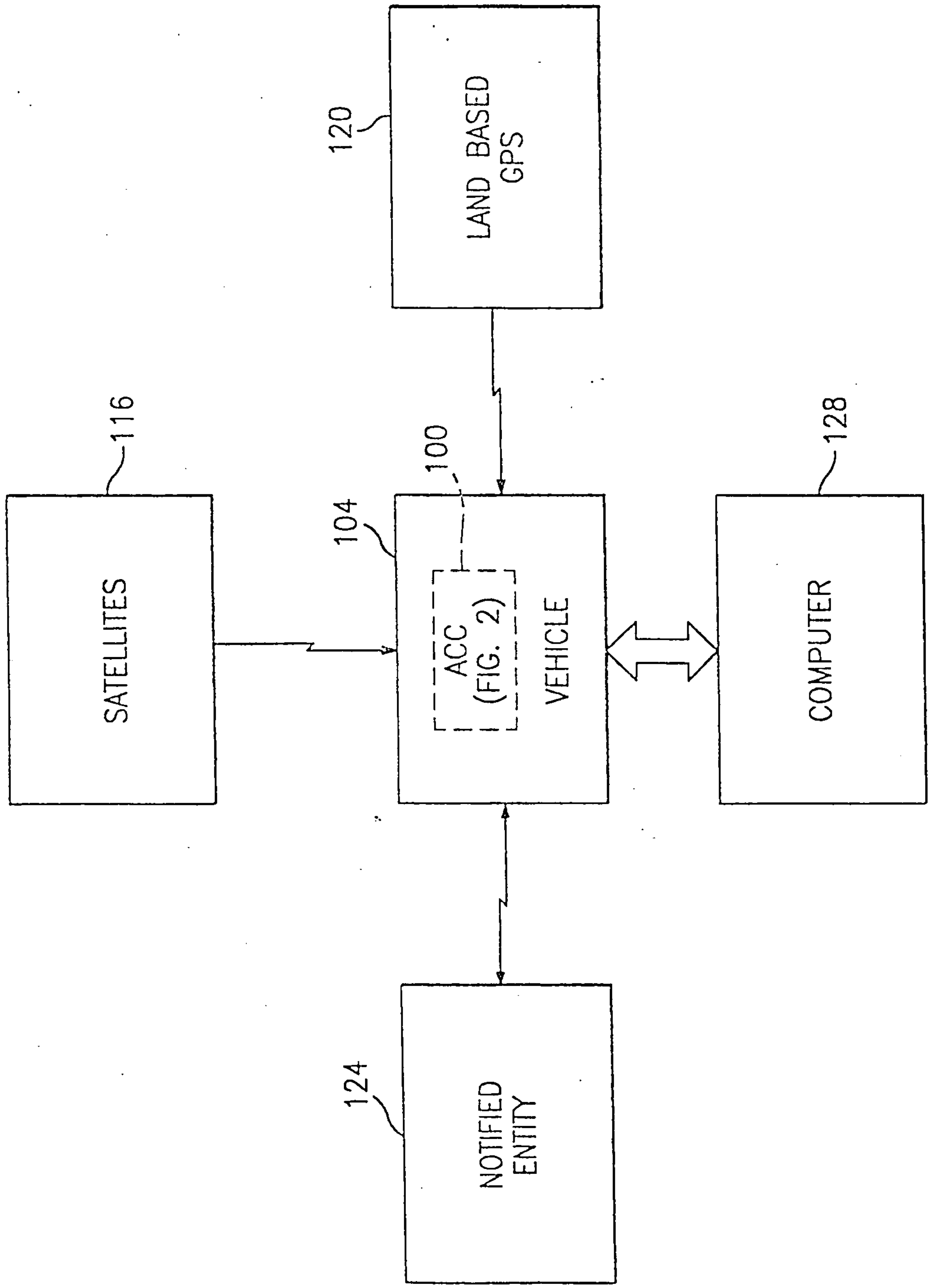
LAND BASED GPS
120
SATELLITES
116
ACC (FIG. 2)
100
VEHICLE
104
COMPUTER
128
NOTIFIED ENTITY
124

FIG. 1

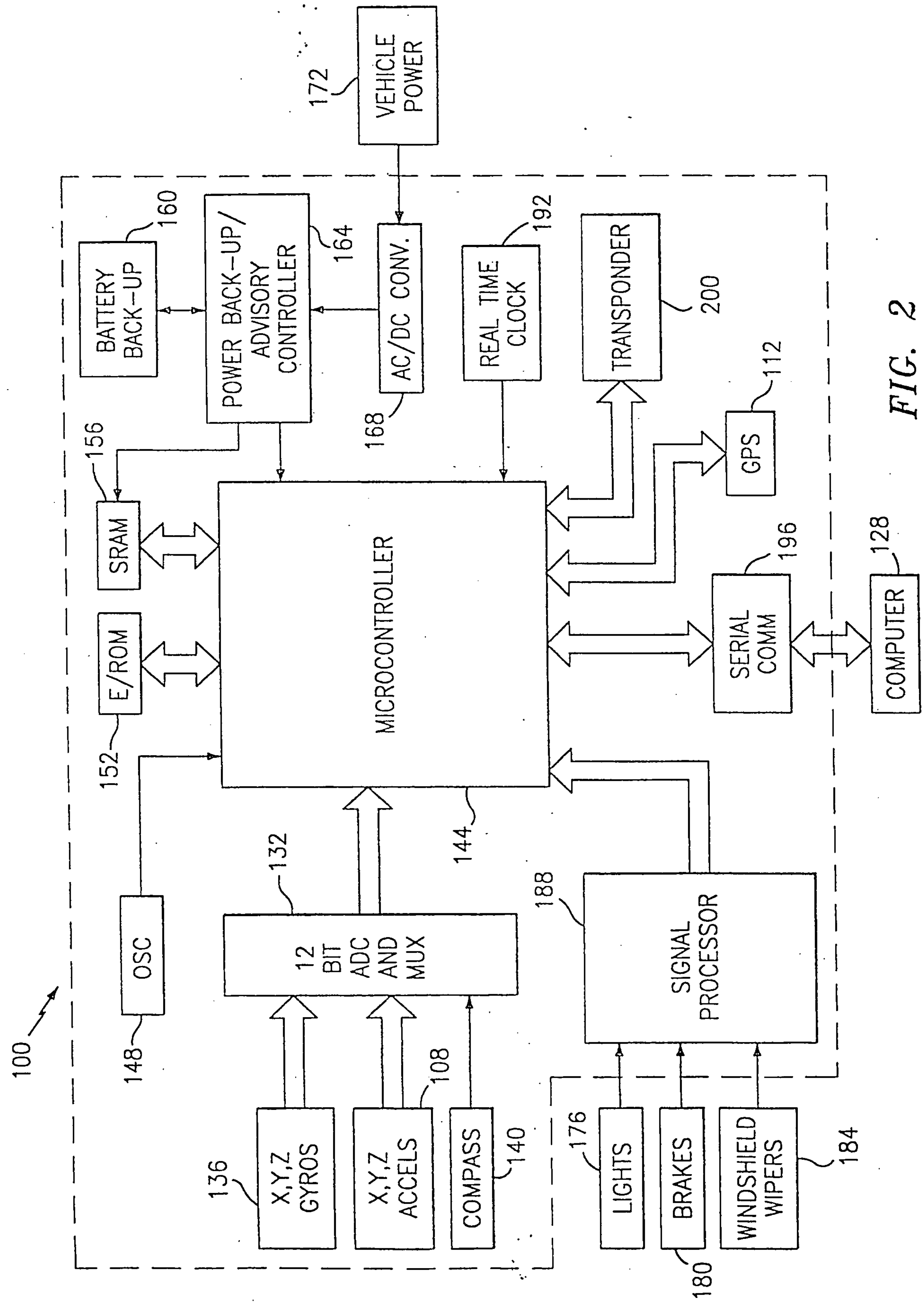
VEHICLE POWER
172
BATTERY BACK-UP
160
POWER BACK-UP/ ADVISORY CONTROLLER
164
AC/DC CONV.
168
REAL TIME CLOCK
192
TRANSPONDER
200
GPS
112
SRAM
156
E/ROM
152
MICROCONTROLLER
144
SERIAL COMM
196
COMPUTER
128
OSC
148
12 BIT ADC AND MUX
132
SIGNAL PROCESSOR
188
X,Y,Z GYROS
136
X,Y,Z ACCELS
108
COMPASS
140
LIGHTS
176
BRAKES
180
WINDSHIELD WIPERS
184
100

*FIG. 2*

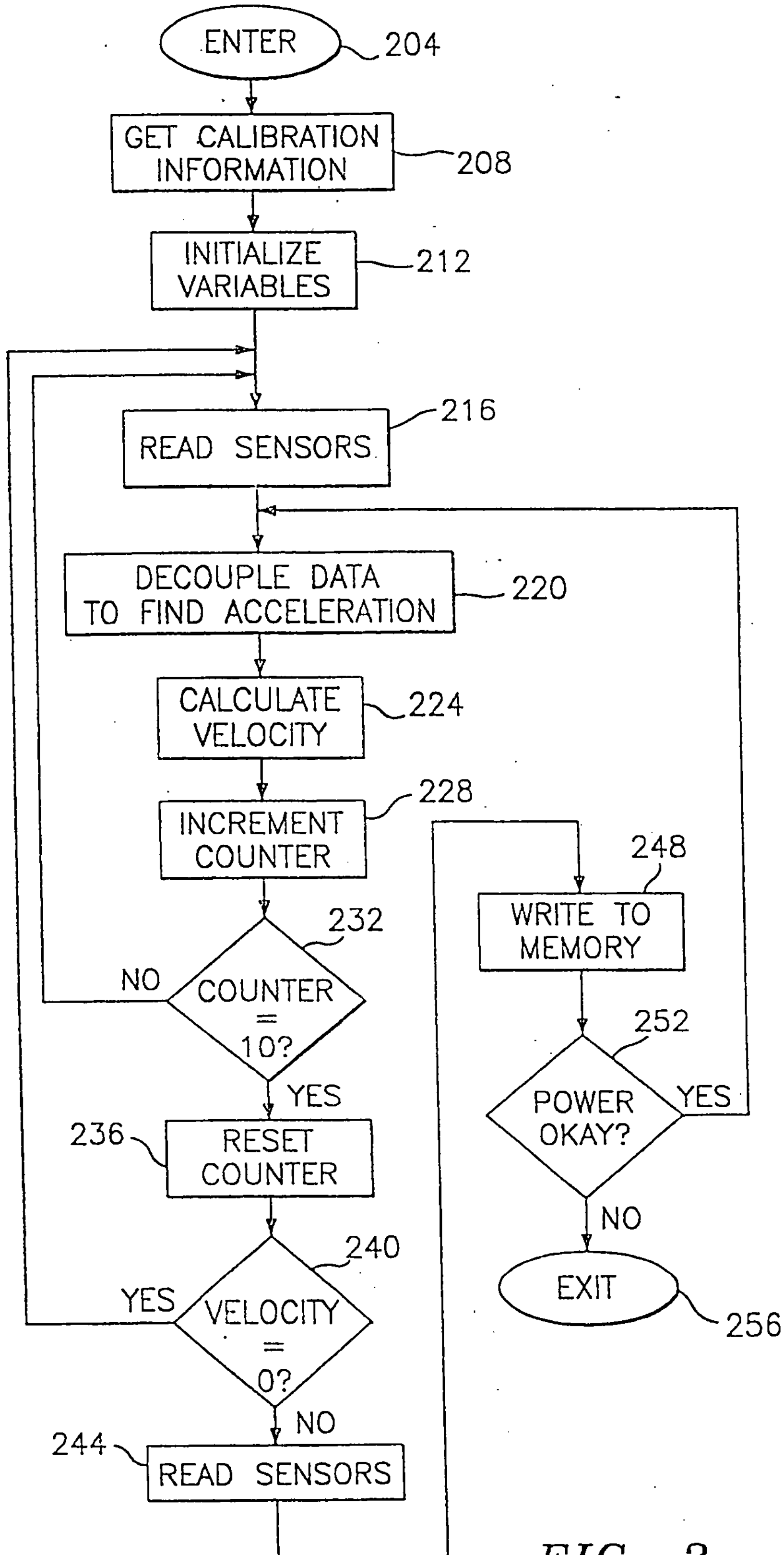
ENTER
204
GET CALIBRATION INFORMATION
208
INITIALIZE VARIABLES
212
READ SENSORS
216
DECOUPLE DATA TO FIND ACCELERATION
220
CALCULATE VELOCITY
224
INCREMENT COUNTER
228
COUNTER = 10?
232
NO
YES
RESET COUNTER
236
VELOCITY = 0?
240
YES
NO
READ SENSORS
244
WRITE TO MEMORY
248
POWER OKAY?
252
YES
NO
EXIT
256

FIG. 3